



1999

Etiology and Treatment of Rotator Cuff Injuries in Baseball Pitchers

Jeff Breyen

University of North Dakota

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ETIOLOGY AND TREATMENT OF ROTATOR CUFF INJURIES IN BASEBALL
PITCHERS

by

Jeff Breyen
Bachelor of Science in Physical Therapy
University of North Dakota, 1998

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

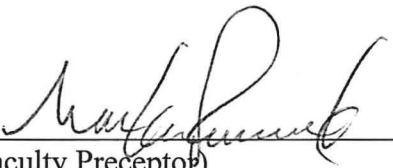
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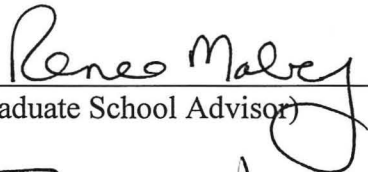
Master of Physical Therapy


Grand Forks, North Dakota
May
1999



This Independent Study, submitted by Jeffrey J. Breyen in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.


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ACKNOWLEDGEMENTS

I would first and foremost like to thank my family for all of their support during my five year stay in Grand Forks. I would also like to thank my puppy Fritz for all of the laughs he provided me for 12 years. Not far down on my list would be Mark Romanick for all of his help with my review, and essentially confirming my interest in the sports medicine field of physical therapy. I would like to thank all of my instructors and classmates for three years of fun, fun, fun! I wish all of them the very best, and feel lucky to have gotten to know each of them. Lastly, I must thank Student Loans of North Dakota (SLND) for without them I would never have paid so much for my education.

ABSTRACT

Rotator cuff injury is one of the most common shoulder problems seen in the baseball pitchers today. The rotator cuff is the primary dynamic stabilizer of the glenohumeral joint and is placed under significant stress during each pitch the player delivers to the plate. Rotator cuff injury and dysfunction in the baseball pitcher may be classified based on etiology as primary impingement, primary tensile overload, instability, and macrotrauma.

The shoulder is a complex joint and proper treatment relies on the physical therapist's knowledge of the anatomy and function of all of the involved structures about the shoulder. The therapist must also know how the structures work together to promote the smooth, coordinated movements necessary for normal arm motion. A thorough history and physical examination are paramount in the evaluation, classification, and treatment planning of the athlete with rotator cuff pathology, which is the focus of this literature review.

Chapter 1

Introduction

In 1974, Nolan Ryan threw the fastest ever recorded pitch at an amazing 101 miles per hour.¹ With the repetition, high velocity and incredibly high forces that act on the shoulder joint complex during pitching, he is fortunate to have never suffered any major rotator cuff injuries during his 20 plus year major league career. However, rotator cuff injuries have long been the fear of professional and amateur pitchers alike. A torn rotator cuff once meant certain retirement, though surgical repair could salvage recreational use of the shoulder.² Today, however, through advanced surgical procedures, an athlete who suffers a cuff injury is usually only out for a season, and, through intense rehabilitation, is able to return to his prior level of pitching. These advanced treatment techniques are used more and more often as shoulder injuries are appearing more frequently than ever. The increased frequency can be attributed to the increased interest in athletics stemming from a more health conscious general population coupled with parents starting their children in sports activities at much earlier ages. Along with this increase in the number of injuries has come an influx of information pertaining to the evaluation and treatment of shoulder joint complex injuries, especially in athletes.³

The shoulder is a highly mobile joint complex with an estimated 16,000 positions differentiated by one degree, making it more mobile than any other joint in the body.^{3,4} Overhead throwing athletes, such as baseball pitchers, usually add to the complexity by

demonstrating excessive external rotation (greater than 145°) and a decreased internal rotation (75° or less) about the shoulder. This alteration in normal range of motion is secondary to repetitive stresses of pitching resulting in an acquired laxity in anterior structures. There is also a loss of flexibility in the posterior muscles and joint capsule which may in effect cause the humeral head to ride anteriorly during pitching.³ The excessive mobility in pitchers that results from external rotation, anterior humeral head displacement, great force, and repetition puts the ligamentous and muscular structures about the shoulder in a vulnerable position, almost inviting injury.^{3,4}

With throwing being a skill second only to running as a common element in sports and the notion that compared to all other overhead throwing activities, pitching a baseball is perhaps the most dynamic, it becomes clear that this precarious balance between excessive mobility and challenged stability of the glenohumeral joint is tested with every game, practice, or warm-up pitch these athletes make.^{3,4,5,6} With pitchers often throwing in upwards of 120 pitches per game, the potential for overuse injury increases dramatically, as the repetition may lead to microtrauma of the musculotendinous stabilizers, the rotator cuff muscles, around the shoulder.³

Jobe⁴ doesn't separate shoulder injuries into separate disorders, but rather states that instability is a continuum of the same disease that begins with overuse and can lead to a rotator cuff tear if left untreated. Likewise, Neer⁷ has his own classification system for rotator cuff injuries in which he divides into three stages of lesion based on how acute or chronic the injury is and if any bony alterations in the anatomy of the subacromial space are causing impingement. Current trends in classification of rotator cuff injuries

categorize the injury based on the mechanism of injury. There have been many fluctuations in the number of categories used, but the most common scheme divides it into four types of mechanism of injury. This review will discuss these four categories of primary impingement, primary tensile overload, instability, and macrotrauma as possible mechanisms of injury to the rotator cuff of a baseball pitcher.^{8,9,10}

In diagnosing a rotator cuff injury, a thorough, detailed history of the onset, character, duration and nature of the symptoms is essential.⁸ Rotator cuff pathology in pitchers will usually manifest as pain during the throwing motion with the athlete often complaining of a vague loss of pitching velocity, power, and endurance and an increased time needed to warm up to get rid of stiffness.^{8,10} A physical examination consisting of palpation, passive and active range of motion assessment, and special tests will also be needed to enable the examiner to accurately determine the nature of the athlete's problem.^{8,11}

In the past the rehabilitation process following shoulder injury or surgery was frequently delayed several weeks to allow the patient to become comfortable and to ensure early healing of the injured or repaired structures. Postoperative management frequently consisted of several weeks of immobilization followed by passive motion exercises only.^{12,13,14} Currently, the trend in rehabilitation has moved toward earlier protected motion and strengthening activities for the operative patient while nonoperative treatment is directed at strengthening of the rotator cuff, decreasing inflammation, and regaining lost range of motion.^{8,15,16}

The purpose of this literature review is to gain and give an understanding of the diagnosis and treatment techniques currently used to rehabilitate a patient with a rotator cuff injury. This review will focus on diagnosis and treatment of baseball pitchers. In the subsequent chapters, rotator cuff injuries will be examined in greater detail beginning with a close look at the anatomy of the rotator cuff region and biomechanics of pitching a baseball. Focus will then shift to the classification based on mechanism of injury. The fourth chapter will cover the evaluation and diagnosis process. An in-depth discussion of treatment and rehabilitative techniques will conclude the review.

Chapter 2

Anatomy and Biomechanics

ANATOMY

The shoulder is one of the most complex articulations in the body with 3 bones, 4 joints, 12 ligaments, and 15 muscles. This complex arrangement of structures allows for the glenohumeral joint to be the most mobile in the body with an estimated 16,000 positions differentiated by one degree.^{3,4} While this review focuses on the rotator cuff and injuries to it, to fully understand the possible mechanisms of injury, one needs to be familiar with the functional anatomy and biomechanics of the entire complex area.

This chapter will next discuss the anatomy of the shoulder before moving into the biomechanics of pitching a baseball. The shoulder joint, as previously mentioned, consists of four joints that function in a precise, coordinated, and synchronous manner with position changes of the arm involving movement of the clavicle, scapula, and humerus bones. These movements are the result of the combined work efforts of the sternoclavicular, acromioclavicular, and glenohumeral joints and the scapulothoracic gliding mechanism.^{17,18} It is those combined efforts that provide the upper limb a range of motion exceeding that of any other joint mechanism.^{3,4,17,18} For a better understanding of each joint, an in depth look at each of the four will follow.

Sternoclavicular (SC) Joint

The sternoclavicular (SC) joint is a saddle type of synovial joint composed of two relatively incongruent surfaces, the medial end of the clavicle, and the posterolateral aspect of the sternal manubrium and first rib.^{18,19} The articular surfaces are separated by a strong, thick fibrocartilaginous articular disc, which aids in improving the joint congruency and shock absorption and in preventing medial displacement of the clavicle.^{17,18,19} It is the only bony articulation between the upper limb and the axial skeleton and has the important function of using the clavicle as a strut, holding the upper limb away from the trunk to allow for maximum freedom of motion.^{17,18}

A fibrous capsule surrounds this entire joint with the SC and interclavicular ligaments reinforcing it anteriorly, posteriorly, and superiorly.¹⁷ The costoclavicular ligament ascends from the first rib and its costal cartilage to the inferior margin of the medial end of the clavicle. This ligament serves as a major stabilizing structure, limiting elevation of the arm and protraction of the shoulder.^{18,19}

Despite the saddle like form of the SC joint, it moves in many directions much like a ball and socket joint would, allowing approximately 40° of motion in all planes, which aids in permitting a high degree of global shoulder motion.² Movement of the SC joint allows elevation and depression of the clavicle as well as protraction and retraction. The axis for both movements lies close to the clavicular attachment of the costoclavicular ligament.^{17,18,20}

Acromioclavicular (AC) Joint

The acromioclavicular (AC) joint is a plane synovial joint formed by the lateral end of the clavicle and the acromion of the scapula.^{17,18,19,20} This articulation is also

relatively incongruent, with the joint line oblique and slightly curved. The curvature of the joint permits the acromion, and thus, the scapula, to glide forward or backward over the lateral end of the clavicle. This movement of the scapula keeps the glenoid fossa continuously facing the humeral head.¹⁷ The oblique nature of the joint is such that the forces transmitted through the arm will tend to drive the acromion under the lateral end of the clavicle.^{17,18,19}

Stability of the AC joint is dependant upon the superior and inferior AC ligaments that reinforce the weak joint capsule. In addition, the coracoclavicular ligaments unite the clavicle and coracoid process and forms the most efficient means of preventing the clavicle from losing contact with the acromion.^{17,18} This ligament is divided into two individual components, the conoid and trapezoid ligaments (see Figure 1). The conoid portion lies posterior and medial to the trapezoid and runs superiorly and slightly posteriorly from the upper surface of the coracoid process to attach to the undersurface of the clavicle, thus limiting superior and anterior movement of the clavicle on the acromion. The trapezoid ligament runs from the anterior coracoid process to the inferior clavicle and functions to prevent overriding of the clavicle on the acromion. Tension in the conoid ligament during arm elevation results in dorsal axial rotation of the clavicle about its long axis. This rotation is necessary for full elevation of the upper extremity.^{17,18,19}

The AC joint allows 20° to 30° of movement of the scapula on the clavicle in three planes. Rotation occurs about coronal, sagittal, and vertical axes. It permits continued lateral rotation of the scapula after about 100° of abduction when SC

movement is restrained by the SC ligaments.¹⁷ Functionally, the two major movements at the AC joint are a gliding movement as the shoulder flexes and extends and an elevation and depression movement to conform with changes in the relationship between the scapula and humerus during abduction.^{17,18} The AC joint is important because it

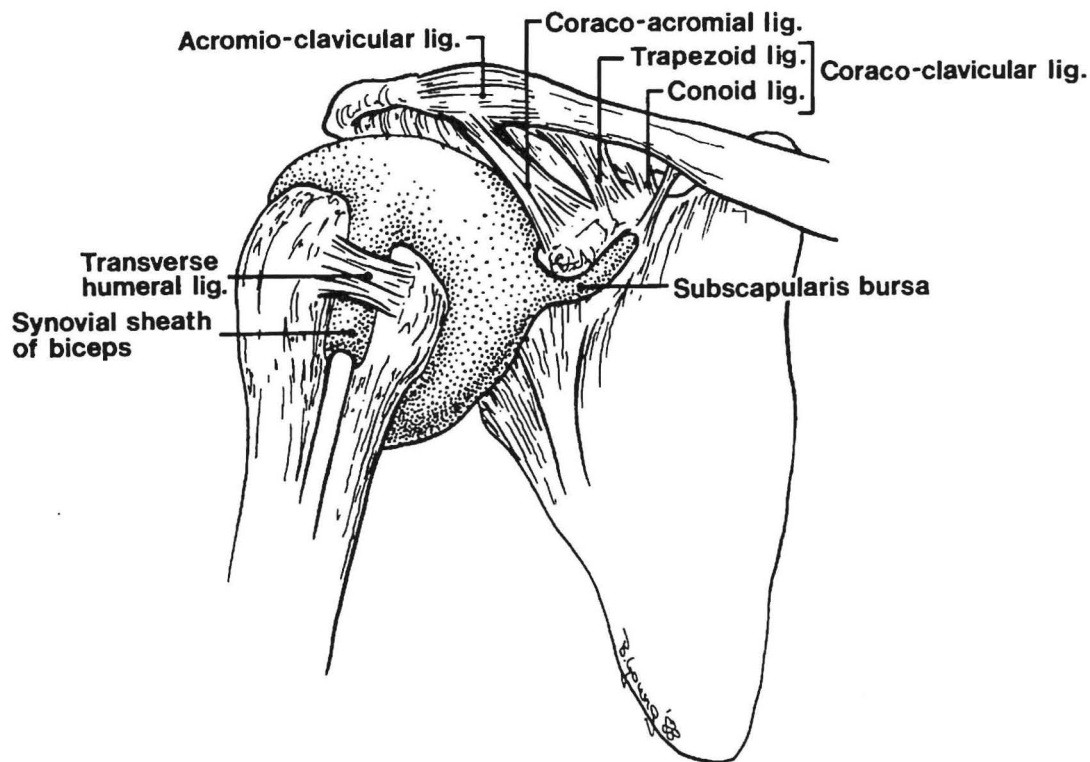


Figure 1. Ligaments Around the Shoulder. (From Rockwood²¹ with permission)

contributes to total arm movement in addition to transmitting forces between the clavicle and acromion.²⁰

Scapulothoracic Gliding Mechanism

The scapulothoracic joint, or gliding mechanism, consists of the anterior concave surface of the scapula riding over the posterolateral convex surface of the thoracic cage. Except for its ligamentous attachments through the AC and SC joints, the scapula has no

bony or ligamentous connection to the thorax. In movements of the shoulder complex, the scapula can be protracted, retracted, elevated, depressed, and rotated about a variable axis perpendicular to its flat surface.¹⁷

Glenohumeral (GH) Joint

The glenohumeral (GH) joint is a multiaxial ball and socket synovial joint between the humeral head and the glenoid fossa of the scapula.^{17,20} It permits a wide range of motion; however, this mobility is gained at the expense of stability. The shallowness of the glenoid fossa and disproportionate size and lack of congruency of the articular surfaces are what make this joint inherently unstable.^{18,20} The shallow glenoid cavity accepts little more than one third of the large humeral head at any one time, but is deepened slightly and enlarged by the fibrocartilaginous glenoid labrum.^{17,18,19,20}

It is generally accepted that the glenoid labrum, which attaches around the margin of the glenoid fossa, assists in lubrication, protection, and deepening of the GH joint (see Figure 2).²⁰ This deepening increases the contact of surface of the humeral head with the glenoid to approximately three fourths.¹⁹ The labrum, in and of itself, does not appear to add to the stability of the joint, but its shape adapts to accommodate rotation of the humeral head, adding flexibility to the edge of the glenoid fossa.¹⁷

The fibrous capsule enclosing the shoulder joint is thin and loose, and by itself would contribute little to stability of the joint. The integrity of the capsule and maintenance of the normal glenohumeral relationship depends on the reinforcement of the capsule by ligaments and the attachment of the muscle tendons of the rotator cuff mechanism. The intrinsic ligaments which help strengthen the shoulder joint include the

superior, middle, and inferior glenohumeral ligaments as well as the coracohumeral and transverse humeral ligaments (see Figure 2).^{17,18,19,20}

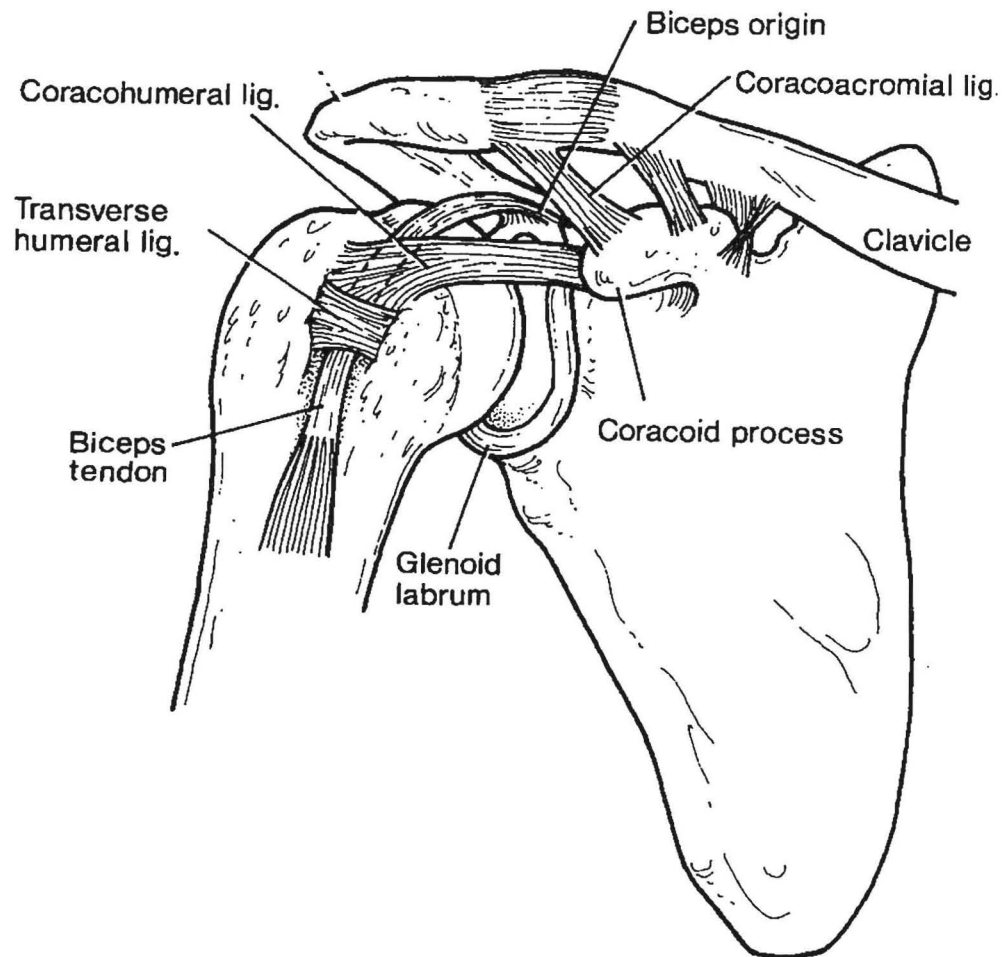


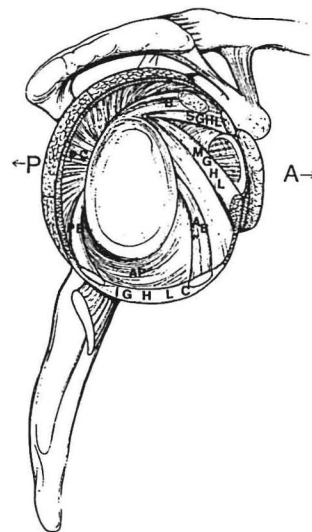
Figure 2. Ligaments Around the Shoulder 2. (Adapted from Andrews²² et al).

The coracohumeral ligament extends from the base of the coracoid process to the top of the bicipital groove on the greater tuberosity (see Figure 2). It covers the interval

between the supraspinatus and subscapularis and is an important stabilizing ligamentous structure in the shoulder complex. This ligament is vital in maintaining the glenohumeral relationship as the pull of gravity is counteracted largely by it and the superior capsule. It is responsible for checking lateral rotation and extension of the shoulder.^{17,18,19,20}

Underneath the coracohumeral ligament is the superior glenohumeral ligament which runs from the superior glenoid labrum to the upper segment of the lesser tuberosity. The middle glenohumeral ligament originates from the anterosuperior portion of the labrum and is directed slightly inferiorly in an oblique direction to insert along the medial aspect of the lesser tuberosity. The inferior glenohumeral ligament is the thickest of the three and reinforces the inferior capsule. It stretches from the inferior labrum to attach onto the inferior neck of the humerus. The transverse humeral ligament forms a bridge over the intertubercular groove and long head of the biceps tendon, which is often an involved structure in rotator cuff pathology. These ligaments aid in reinforcing the capsule anteriorly and in the case of the inferior glenohumeral ligament, inferiorly, but offer little restraint to glenohumeral movement posteriorly (see Figure 3).^{18,19,20}

Figure 3.
Glenohumeral
Ligaments. (From
Rockwood²¹ with
permission)



Another structure that plays an important role in rotator cuff and glenohumeral function is the coracoacromial arch. It is formed by the coracoid process, acromion, and coracoacromial ligament. The coracoacromial ligament is a triangular band with an origin at the lateral coracoid process and an apex attachment to the superior aspect of the acromion.^{17,18,19,20} When force is transmitted superiorly along the humerus, the head of the humerus is pressed against this protective arch. Between the coracoacromial ligament and the underlying humeral head is the subacromial space. In this space lies the rotator cuff tendons and the subacromial bursa. The bursa separates the coracoacromial arch and the deltoid muscle superiorly from the biceps tendon and rotator cuff below, allowing for a smooth gliding between these structures and reducing friction on the tendons as they pass under the arch.^{17,18,19}

Muscles of the Rotator Cuff

There are 15 muscles that act on the shoulder complex. Muscles that control the scapula and its motions are essential to the overall coordinated movement of the shoulder complex. Their proper function is vital to the normal biomechanics of the shoulder during pitching as well as every day activities of daily living as these muscles place the glenoid fossa in the optimal position for the activities being performed.²² These muscles are the serratus anterior, trapezius, levator scapulae, rhomboids major and minor, latissimus dorsi, and pectoralis major. Table 1 lists the actions of the scapula and the muscles of the scapula that perform these actions. Table 2 lists actions of the humerus and the muscles that perform these actions. These tables are provided as a quick reference to the muscles about the shoulder and scapula. This review will focus on the

muscles of the rotator cuff, or SITS muscles (supraspinatus, infraspinatus, teres minor, and subscapularis), and will take a brief look at the biceps muscle, which is often implicated in cuff injuries.

TABLE 1. MUSCLES INVOLVED IN SCAPULAR MOTION

<u>Action</u>	<u>Muscles</u>
Scapular Elevation	Upper Trapezius, Levator Scapulae, Rhomboids Major and Minor
Scapular Depression	Lower Trapezius, Pectoralis Major and Minor, Latissimus Dorsi
Scapular Abduction	Serratus Anterior, Pectoralis Major and Minor
Scapular Adduction	Trapezius, Rhomboids Major and Minor
Upward Rotation	Serratus Anterior, Upper and lower Trapezius

TABLE 2. MUSCLES INVOLVED IN SHOULDER MOTION

<u>Action</u>	<u>Muscles</u>
Flexion	Anterior Deltoid, Coracobraccialis
Extension	Latissimus Dorsi, Posterior Deltoid, Teres Major
Abduction	Deltoid, Supraspinatus
Adduction	Latissimus Dorsi, Pectoralis Major, Teres Major
External Rotation	Infraspinatus, Teres Minor, Posterior Deltoid
Internal Rotation	Pectoralis Major, Latissimus Dorsi, Teres Major, Subscapularis

The SITS muscles are a musculotendinous complex formed by the attachment to the capsule of the supraspinatus superiorly, infraspinatus and teres minor posteriorly, and

the subscapularis anteriorly (see Figure 4).¹⁷ The tendons of the rotator cuff blend with the shoulder capsule as they insert into the humerus. They function to provide dynamic stabilization of the glenohumeral joint during pitching by holding the humeral head close

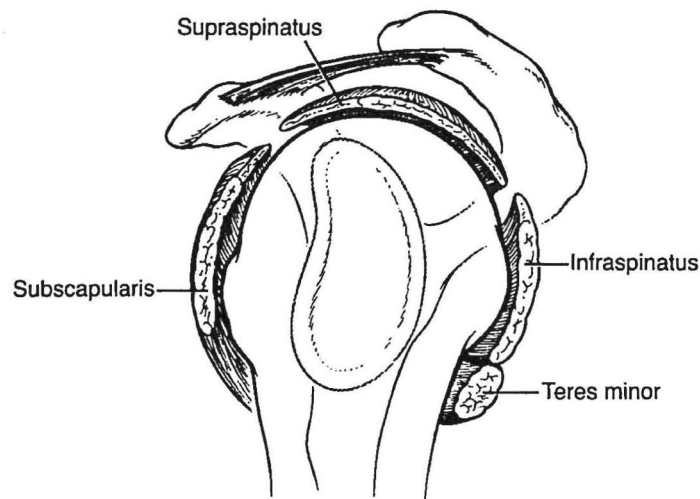


Figure 4. Sagittal View of Rotator Cuff Musculature
(From Rockwood²¹ with permission).

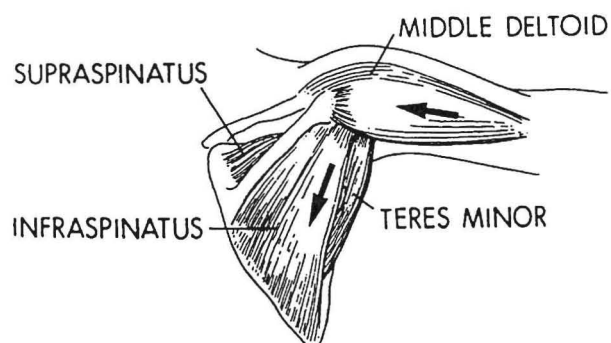
to the glenoid and give the shoulder stability in several positions, especially abduction of the arm.^{1,3,18,19,20}

The supraspinatus muscle arises from the supraspinous fossa and passes laterally under the coracoacromial arch to attach to the greater tuberosity. It is innervated by the suprascapular nerve and functions to initiate abduction of the arm. Peak activity of this muscle occurs after abduction of the arm in the late cocking phase of pitching. The infraspinatus originates in the infraspinous fossa and travels laterally to insert on the posterior aspect of the greater tuberosity. Like the supraspinatus, it is also innervated by the suprascapular nerve, but functions to laterally rotate the arm. During throwing, the

infraspinatus muscle supplies approximately 90% of the external rotation power, with peak activity during the late cocking phase. The teres minor runs from the upper two-thirds of the lateral border of the scapula, passes deep to the long head of the triceps and inserts at the lowest facet of the greater tuberosity. It is supplied by the axillary nerve and its action is external rotation of the arm. The subscapularis originates in the subscapular fossa and inserts on the lesser tuberosity of the humerus. The tendinous portion of this muscle becomes adherent to the anterior joint capsule of the shoulder near its insertion on the humerus. It has innervation through the upper and lower subscapular nerves and functions to internally rotate, adduct, and flex the arm and check posterior translation of the humerus.^{2,5,19,23} Peak activity in throwing occurs during the late cocking phase as it is eccentrically contracting to protect the anterior shoulder joint.⁵

The muscles of the rotator cuff work together as the dynamic stabilizers of the arm during pitching, but the deltoid also forms an important force couple with the rotator cuff muscles, specifically the supraspinatus and infraspinatus (see Figure 5). The

Figure 5. Force Couple of the Deltoid, Supraspinatus, and Infraspinatus Provides a Depression Force to the Humeral Head. (From Andrews²² et al with Permission).



synergistic action of the infraspinatus and supraspinatus provides a depression force to counteract the deltoid muscles' upward shear force, thus depressing the humeral head during dynamic activities such as pitching.²²

Another significant structure of the rotator cuff complex is the rotator interval. The rotator interval is the space between the superior border of the subscapularis tendon and the anterior border of the supraspinatus tendon (see Figure 6). This interval in the rotator cuff tendons contains the superior glenohumeral and coracohumeral ligaments. It functions in providing inferior stability to the shoulder, owing to the presence of the superior glenohumeral ligament in this area. The rotator interval can tear and enlarge when the shoulder dislocates anteroinferiorly. The structure is an important anatomical landmark in surgeries of the shoulder.²²

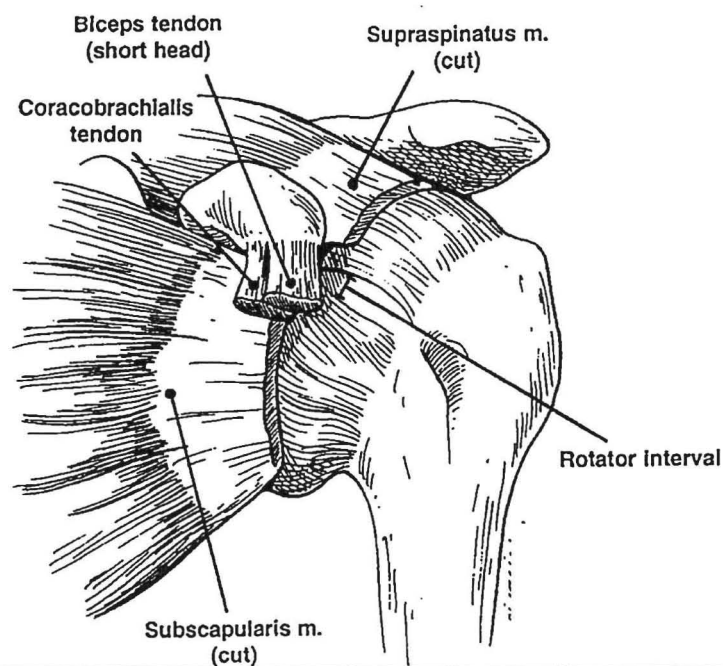


Figure 6. Anatomy of the Rotator Interval. (From Andrews²² with Permission).

The vascular supply to the rotator cuff has been studied and the supraspinatus is noted to have a small area of avascularity about one cm from its insertion. This area of compromised vascularity with the arm in the dependent position is known as the critical

zone. The critical zone has been implicated as the cause of degeneration of the supraspinatus tendon and as a contributing cause of rotator cuff tears.^{2,19}

The biceps brachii functions to supinate the arm, flex the elbow, and flex the shoulder. It originates via the long head at the superior border of the glenoid and by its short head at the coracoid process. Because of its attachment to the glenoid, it has been implicated as a deforming force in causing superior labral tears in pitchers. Its function is thought by some to act as a depressor of the humeral head when the arm is in external rotation, because in this position it travels over the top of the humeral head.^{2,19}

The humeral rotators act in synchrony with the deltoid, which is responsible for arm elevation and active forward flexion and abduction of the humerus during the windup phase of pitching.¹⁹ Each phase of pitching and the biomechanics involved in them will follow.

BIOMECHANICS OF PITCHING

Baseball pitching is an activity that represents the extreme end of the spectrum of demands placed on an athletic shoulder.³ It requires coordination of the pelvis and trunk, strength and endurance of the lower extremities, and an appropriate balance of stability and flexibility of the capsular structures of the shoulder.²⁴ Throwing places large demands on the glenohumeral and scapular musculature in accelerating and, more importantly, decelerating the extremity.³ Enormous torques exceeding 14 000 in-lb are generated about the shoulder during a pitch with humeral angular velocities up to 7 000 °/sec. In fact, the pitching arm has approximately four times the kinetic energy than the leg during a kick.^{3,5,24} This review will divide pitching into six phases to give the reader a

better understanding of the biomechanics of pitching. These six phases include: windup, stride, arm cocking, arm acceleration, arm deceleration, and follow through (see Figure 6 A - K).

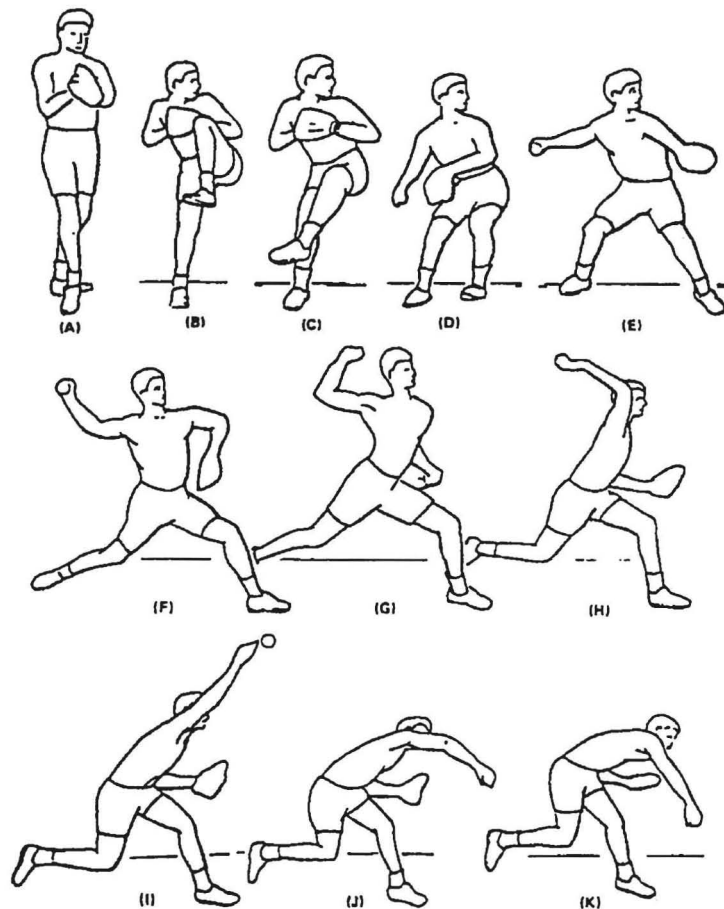


Figure 7. Six Phases of Pitching: windup (A-C), stride (C-F), arm cocking (F-H), arm acceleration (H-I), arm deceleration (I-J), and follow through (J-K). (From Dillman⁵ et al with Permission).

Windup

The purpose of the windup is to put the athlete in a good starting position to pitch.² Pitching has evolved into a downhill throwing skill from a mound with a vertical

height of 10 in.⁵ From a standing position facing the batter, the pitcher initiates the throw by stepping backward with what will become the stride foot or leg. Weight is shifted from the support foot to the stride foot as the pitcher places the support foot laterally in front of the pitching rubber (fig 6 A). Weight is then shifted back to the support foot and the windup is initiated. This weight shifting sets the rhythm for the delivery of the pitch. As the windup is initiated, the body rotates 90°, and the stride leg is elevated and flexed so that the glove side of the body faces the batter (fig 6 B). From this position, the delivery of the ball to the catcher is initiated.^{5,25} During this phase, the shoulders are partially flexed and abducted, and are held in this position by the anterior and middle deltoids. The supraspinatus and clavicular head of the pectoralis major are also active, but rotator cuff musculature, for the most part, has minimal activity.^{2,19} In addition, elbow flexion is maintained by isometric contraction of the biceps, brachialis, and brachioradialis.^{2,5,25}

Stride

After the windup, the stride leg is directed toward the catcher. Removal of the ball from the glove when the stride is initiated (fig 6 C-E) and the downward and upward motion of the arm ensure that the throwing arm will be properly synchronized with the body. This coordination is critical: if the throwing arm and stride leg are coordinated properly, the arm will be in a semicocked position when the stride leg contacts the ground.⁵

The location of the foot after the stride is very important. The stride foot should land almost directly in front of the back foot, with the toes pointed slightly in. If the foot

is placed too much towards the pitchers throwing arm, the pitcher may end up throwing “across his body,” which means the hips will not be able to rotate and the athlete will throw with little energy contributed from the lower half of the body. Conversely, if the front foot lands toward the glove hand, the pitcher is “too open.” This will cause the hips to rotate too early and energy from the hips will not be able to help the upper trunk rotate.⁵ In either case, the pitcher is left trying to throw with only his arm and no lower body help, thus, leading to increased stress on the rotator cuff muscles.^{5,19}

Arm Cocking

Once the stride is completed, the trunk moves laterally toward the catcher and hip rotation is initiated. Trunk rotation follows the hip and in highly skilled pitchers hyperextension of the upper trunk occurs as it is rotated around to face the plate. As the trunk is undergoing rotation and extension, the upper arm is flexed at the elbow, abducted, and the shoulder undergoes external rotation (cocking of the arm). During this early cocking, the deltoid experiences peak activity holding the arm elevated at 90°. As late cocking occurs, the deltoid activity is diminished and the rotator cuff muscles increase their action with the supraspinatus showing the most intense activity as the arm achieves maximum external rotation. The infraspinatus and teres minor are mainly responsible for the external rotation experienced in this phase, and their action also contributes to the dynamic stability of the shoulder by drawing the head of the humerus toward the glenoid fossa.^{5,19,25} This phase (fig 6 F-H) is concluded by activation of the subscapularis and pectoralis major as they eccentrically contract to protect the anterior glenohumeral joint, which is under extreme tension.^{5,22}

Arm Acceleration

The arm acceleration phase (fig 6 H-I) starts at maximal external rotation and when the elbow begins to extend and the humerus begins to internally rotate about the shoulder. To pitch properly and efficiently, a short delay between the onset of elbow extension and shoulder internal rotation is crucial. This delay allows the pitcher to reduce the arm's rotational resistance about its longitudinal axis, thereby allowing greater internal rotation velocity to be generated.^{5,22}

This phase is very explosive with shoulder internal rotators contracting concentrically to help produce internal rotation angular velocities over 7 000°/sec. For approximately 50 msec, the ball must be accelerated from an essentially stationary position to a speed reaching up to 95 to 100 mph.²⁵ This phase ends when the ball is released. The trunk is in a flexed position, the arm is almost fully extended at the elbow, and the shoulder is undergoing continued internal rotation.^{5,19} The supscapularis is active as it functions as an internal rotator to help carry the arm across the chest during acceleration.¹⁹ In a skilled thrower, the rotator cuff remains relatively quiet during the early phase of acceleration, but it may be very active when an athlete's technique and training biomechanics are suboptimal, thus contributing to increased risk for overuse injury.^{8,19}

Arm Deceleration

After ball release, the arm continues to extend at the elbow and internally rotate at the shoulder. In the arm deceleration phase (fig 6 I-J), shoulder internal rotation angular velocity decreases to zero from its maximum value observed near the time of ball

release.⁵ During this deceleration time, there is a vigorous active deceleration force generated by the posterior shoulder girdle musculature and biceps.²⁵ The rotator cuff muscles, specifically the infraspinatus and teres minor, are acting to aid in slowing down the humeral head and stabilizing the glenoid fossa. These muscles are acting eccentrically at very high forces, which, in effect, is why the majority of the rotator cuff injuries occur during this phase of pitching.^{8,16,17} This is the most active phase of pitching with all cuff muscles firing intensely. The subscapularis is still internally rotating the arm while the deltoid, trapezius, latissimus dorsi, and the rest of the rotator cuff are attempting to decelerate it as it continues into this internal rotation and horizontal adduction position. Arm deceleration ends when the arm has reached an internal rotation position of approximately zero degrees.^{5,19}

Follow Through

The importance of a good follow through is often overlooked. However, it is critical in minimizing the risk of injury. This phase (fig 6 J-K) is the continuation of deceleration. It concludes when all motion is completed and is generally considered a passive phase with the body merely “catching up” with the arm.^{19,25}

The highly dynamic nature of this skill is perhaps best indicated by the fact that the average time from foot contact of the stride leg until ball release is 0.145 seconds. During this time, the ball is typically accelerated from 0 to 95 or 100 mph, and the motions of hip rotation, trunk rotation, upper trunk extension, elbow flexion, shoulder external rotation, elbow extension, hip flexion, upper trunk flexion, shoulder internal rotation and pronation of the forearm are performed in sequence.⁵ This proper timing and

sequence of the motions involved is known as the principles of the “kinetic chain” to biomechanists and coordination or “timing” to athletes.²

Professional pitchers often demonstrate selective use of the individual rotator cuff muscles, such as the ability to use the subscapularis exclusively in acceleration. In contrast, amateur athletes tend to use all the rotator cuff muscles and the biceps to accelerate their pitching arm. Repetition of throwing can thus lead to muscle strains and tendonitis in those pitchers who use muscles unnecessarily. Efficient muscle use learned through training may improve endurance and avoid an injury that is secondary to overuse.^{2,19}

Chapter 3

Classification of Mechanism of Injury

Being able to classify an athlete's type of rotator cuff injury is a useful tool in that it allows the therapist an idea of the direction to take the treatment. However, putting a pitcher into a certain category of injury is not easy to do, as the therapist must not only have a thorough understanding of the anatomy and biomechanics about the shoulder, but must also understand how the injury takes place, in other words, the mechanism of injury.

Repetitive overhand throwing pushes the shoulder to its physiological limits and, therefore, injury states in the throwing shoulder. These injury states do not affect the activities of daily living but become disabling in individuals participating in the high demand sports activity of pitching.³ Jobe et al^{20,26} deserve much of the credit for recognizing the demands placed on the shoulder in throwing and the concomitant pathology that often contributes to degeneration of the rotator cuff complex.

Like Jobe, Neer⁷ is also experienced with shoulder injuries in athletes and is credited with developing a staging system for rotator cuff disease.³ He divides the progression of disease into three stages according to the pathophysiology of cuff degeneration. Stage I lesions are marked by edema and inflammation, usually occur in those younger than 25 years of age, and are reversible with rest and rehabilitation. Stage II lesions are characterized by fibrosis indicating a chronic disease state. These occur in

25 to 40 year olds and are no longer thought to be reversible through conservative management. Stage III injuries involve bony alterations of the subacromial compartment and tears of the rotator cuff tendons and usually occur in those over age 40.⁷

This staging by Neer seems to be an appropriate guideline for most treatments; however, this classification system may not be applicable to the baseball pitcher, because the degenerative process may be accelerated due to the repetitive stress applied to the shoulder during pitching.³ The etiology of rotator cuff pathology in pitchers is probably multifactorial, but cuff injury and dysfunction can be classified based on the mechanism of injury to it.^{3,8,9}

Jobe⁹ prefers to classify rotator cuff pathology into two distinct categories of shoulder injury: that which occurs in those over age 35 and that which occurs in those 35 and younger. In the older population, shoulder injury is generally a result of the degenerative aging process. In the younger population, it is commonly a result of the repetitive nature of an overhand sport, such as pitching a baseball. In numerous studies, classification schemes have listed as few as three and as many as five categories to describe rotator cuff injuries, but the most commonly used number seems to be four definitive types of mechanism of shoulder injury to the rotator cuff.^{3,7,8,9,15} In Jobe's model, which has four groups, an understanding of the rotator cuff pathology in the baseball pitcher and other overhead sports has led to the concept of an instability continuum in which instability leads to subluxation which leads to impingement which then leads to rotator cuff tears. Hence, instability, impingement, and rotator cuff tears cannot be treated as separate and distinct disorders in the overhead athlete as one may

soon lead to the other.⁹ Figure 7 illustrates the instability continuum and microtrauma that can result from repetitive stress.

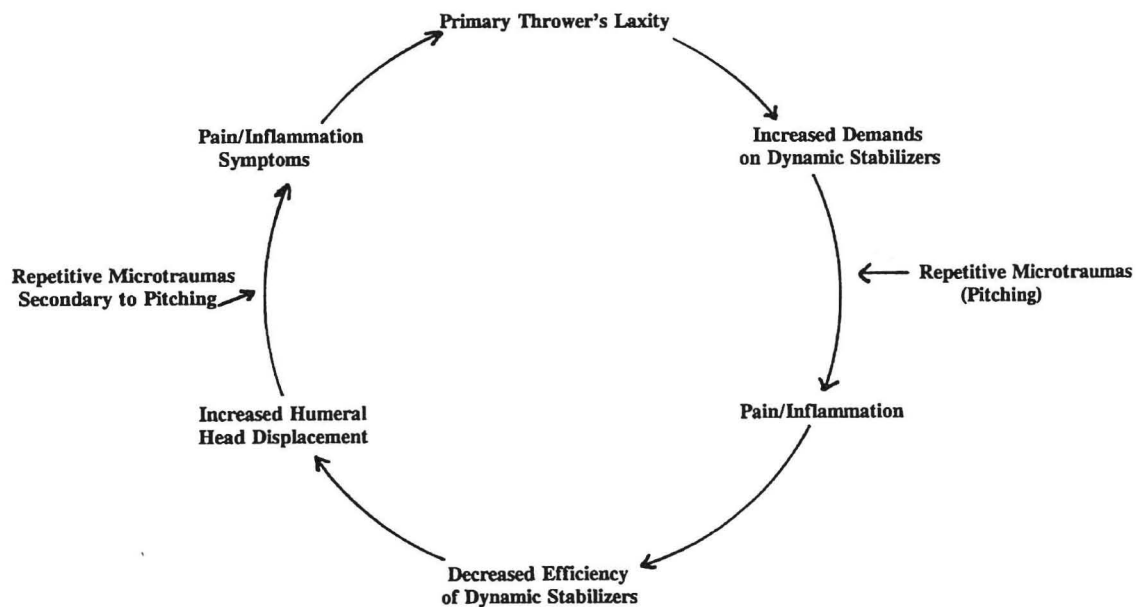


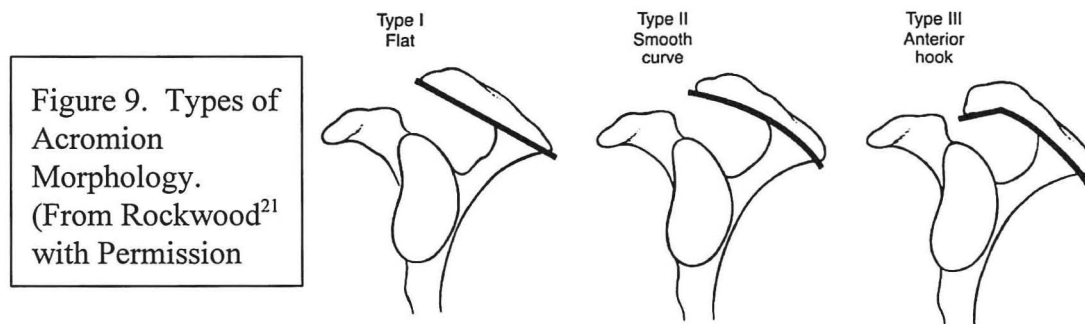
Figure 8. The Microtraumatic Repetitive Stress Cycle. (From Andrews²² with Permission).

Injury in the baseball pitcher usually results from failure due to one or any combination of chronic stress, repetitive tension, or compression of the tissue. Additionally, either mode of failure can be a primary culprit of the injury state or occur secondary to additional pathologies.³ This review will identify four categories of mechanism of injury by combining the efforts of a few studies that have the same basic mechanism of injury but may label the group with another similar name. Next, a detailed examination of each of these categories will be discussed including: primary impingement, primary tensile overload, instability, and macrotrauma.

PRIMARY IMPINGEMENT

Primary impingement of the rotator cuff encompasses those pitchers with pure and isolated impingement and no true instability. It results from direct compression of the cuff tissue against anything encroaching on it inside the tight subacromial compartment between the undersurface of the acromion and the humeral head. This direct compression impedes normal gliding of the rotator cuff tendon complex.^{3,8,9} The pitching motion requires the arm to be abducted to 90° while being repetitively and rapidly submitted into internal rotation and horizontal adduction movements. The overhead thrower often exhibits a loss of internal rotation motion and excessive external rotation movement due to adaptive capsular changes. This motion compensation results in excessive anterior capsule laxity and tightness posteriorly. This posterior tightness may cause the humeral head to migrate anteriorly and superiorly during the overhead throwing motion, which in turn leads to impingement signs as the rotator cuff is impinged. Thus, one of the primary goals for this type of patient is restoration of internal rotation, thus diminishing the anterior humeral head movement and allowing for a greater area for stress absorption.²²

The morphology of the acromion has also been implicated as a risk factor for



rotator cuff pathology. Three acromion types have been described: flat, curved and

hooked (see Figure 9). A noted increased incidence of pathology has been found with a hooked acromion, or os acromiale, as it limits the available subacromial space.^{3,8,11,27} In some instances a congenitally thick coracoacromial ligament or prominent coracoid process may cause direct compression of this space and thus, the rotator cuff complex.³

In younger pitchers, identified as those under age 35, true primary impingement without one of the associated morphological abnormalities is uncommon. In those pitchers who do have primary impingement, acute conditions cause swelling and inflammation within the tendon complex, leading to further compromise of the gliding space (effectively narrowing it) and exacerbating the condition.^{8,28} In the chronic state, scarring occurs as a result of a localized synovial reaction. Primary impingement of this already compromised region only further weakens it and its involved tissues. The tendon fibers become more susceptible to damage allowing for mechanical insult and microtrauma to occur, which, if chronically left untreated, may result in a full thickness tear of the rotator cuff.^{3,8} Pitchers with this diagnosis will demonstrate a positive impingement sign and an arthroscopic examination is likely to reveal rotator cuff lesions of the bursal surface and may reveal pathological factors such as subacromial spurs.^{3,9}

PRIMARY TENSILE OVERLOAD

In pitchers, the rotator cuff can be primarily stressed beyond its ability to adapt and heal, resulting in tendon collagen fiber failure, inflammation, and degeneration (called primary rotator cuff failure).^{3,8} Injury to the cuff occurs as it resists horizontal adduction, internal rotation, anterior translation, and glenohumeral distraction forces found in the deceleration phase of pitching.³ This stress beyond normal limits is usually

due to a sudden increase in the intensity or duration of pitching beyond a level to which the athlete is accustomed. If injury occurs during training, it is commonly due to overuse.^{3,10} The resulting soreness or muscle fatigue about the shoulder may result in altered pitching mechanics, thus increasing the demand placed on the rotator cuff musculature. This overuse injury usually does not progress to a full thickness tear, but instead microtrauma and partial tears are found in the undersurface region of the supraspinatus tendon which may extend posteriorly to the area of the infraspinatus tendon.^{3,9}

INSTABILITY

Although cuff injury can result purely from overuse and impingement, it is clear that subtle anterior glenohumeral instability can result in secondary tensile failure and secondary impingement. This is frequently seen in pitchers as it accompanies the microtrauma that comes from overuse.^{3,8,10} In a position of 90° abduction and maximum external rotation as seen in the arm cocking phase of pitching, the anterior capsule and glenohumeral ligaments are the primary static stabilizers resisting anterior translation of the humeral head.^{3,8} These structures are repeatedly placed under stress during pitching and may become compromised and eventually fail. Excessive anterior translation due to failure of these throwing static stabilizers may cause rotator cuff injury by direct compression (secondary impingement) or through increased loads on the cuff that occur during the deceleration phase of pitching (secondary tensile overload).^{3,8,9} This increased stress on the cuff during pitching is produced as it works eccentrically to limit excessive anterior translation of the humeral head and attempts to maintain stability.⁸

Many pitchers demonstrate excessive external rotation and decreased internal rotation of their dominant arm in comparison with their nondominant arm. This is consistent with a lax anterior capsule and tight posterior capsule of the glenohumeral joint.⁸ Harryman et al²⁹ have shown that tightening of the posterior capsule causes increased anterior translation of the abducted, flexed arm, thus increasing anterior shear forces during pitching. In younger pitchers, generalized ligamentous laxity throughout the body may add to this increased anterior translation as it leads to anterior instability, which presents with a positive relocation test (see chapter four).^{3,8,9}

Secondary impingement was originally described as impingement of the supraspinatus under the coracoacromial arch, resulting from instability and rotator cuff dysfunction which, in turn, allow superior and anterior translation of the humeral head during pitching.^{3,8,10} Recently, it has been noted that this mechanism did not explain consistent undersurface partial rotator cuff tears and a fairly normal subacromial space in throwers at the time of arthroscopy. They also felt that secondary tensile overload could not explain undersurface cuff tearing based on electromyograph (EMG) analysis of the supraspinatus never exceeding 60% of its EMG activity during pitching. Instead, a new classification type called “internal impingement” was suggested to help explain their findings.^{8,10,26,30}

Internal impingement is described as pinching of the posterior and superior rotator cuff tendons (posterior aspect of the supraspinatus, anterior aspect of the infraspinatus) between the humerus and posterior glenoid rim in 90 degrees of abduction and maximum external rotation, or the cocked phase of pitching.⁸ Factors that add to internal

impingement include anterior instability, limited upward rotation of the scapula and extension of the abducted, externally rotated arm beyond the plane of the scapula, all of which may lead to failure of the anterior capsule and precede anterior translation.¹⁰ This concept is used less frequently compared to the instability with secondary impingement and secondary tensile overload category but is relatively similar.

Arthroscopic examination of this instability pathology will present with clearly evident microtrauma on the posterior labrum, anterior capsule, and ligaments. The glenohumeral ligaments are lax, especially the inferior glenohumeral ligament which limits external rotation. Also, tears in the undersurface of the supraspinatus and infraspinatus due to secondary impingement and secondary tensile overload (sometimes collectively referred to as “internal impingement”) are evidenced.^{9,10}

MACROTRAUMA

In the case of macrotrauma causing rotator cuff pathology, failure and tearing of the cuff results from a single traumatic event. It is quite rare in athletes under age 40, especially baseball pitchers, and has its predisposition in an accumulation of microtrauma.³ It is likely to involve a contusion to the cuff with acute swelling and inflammation. The subacromial bursa also appears to be involved and may become acutely swollen and inflamed and, eventually, chronically fibrotic and thickened if left untreated.^{3,8,9}

Macrotrauma most often results in instability and acute impingement. The most common scenario is to sustain a longitudinal tear of the rotator cuff (from the impingement) with an avulsion of the greater tuberosity since the tensile strength of bone

is less than that of young, healthy tendon.^{3,8,9} If surgery is indicated, these patients may show evidence of a Bankart lesion and erosion of the posterior humeral head due to the instability.⁹

Chapter 4

Evaluation and Diagnostic Procedures

The successful treatment of rotator cuff injuries in baseball pitchers is largely dependent upon an accurate clinical diagnosis. This process of differentiating the shoulder injury and classifying it into one of the aforementioned categories begins with an on-field evaluation of the athlete provided there is an athletic trainer available at the site of competition. The athletic trainer for an athletic team is at a distinct advantage over other health care providers when attempting to make a diagnosis. First, they may have viewed the mechanism of injury which lends a great deal of insight into the anatomical structures involved. Second, they are able to assess the nature of the injury before the onset of muscle spasm and swelling, both of which are factors that can confound the accurate assessment of severity.^{8,31} This chapter will focus on the evaluation of a rotator cuff injury by the physical therapist in the clinical setting.

In order for an effective program of rehabilitation, the physical therapist must first conduct a thorough, detailed, sequential injury evaluation in the clinic. Included in this evaluation should be a thorough history, physical examination including special tests, and, if possible, imaging studies of the affected area. A detailed history of the athlete will give a good indication as to the onset, character, duration and nature of the shoulder symptoms.^{8,11,31} In addition to specific questions regarding the shoulder symptomatology, it is important to question the pitcher about cervical spine problems and a complete

evaluation of the cervical spine may be necessary to rule out its involvement in the patient's complaints.^{8,11} Rotator cuff pathology in pitchers usually manifests as pain during the throwing motion, and this may be revealed by them during the history portion of the evaluation. Location of pain is also important as it may be associated with the region of injury. For instance, anterior pain may be associated with subscapularis injury, anterolateral pain with supraspinatus pathology, posterior pain with infraspinatus injury, and posterior superior pain during the throwing motion related to internal impingement.^{8,9,10} As is evidenced here, the subjective portion of the therapist's evaluation is essential as it leads in a direction in which to take the physical examination or objective portion of the evaluation.

The physical examination of the athlete will enable the therapist to accurately determine the nature of the problem and classify the shoulder pain and dysfunction, which will help determine which treatment path to take. The rest of this chapter will describe the physical examination appropriate for a shoulder or rotator cuff injury and discuss the use of imaging studies as a useful diagnostic tool.

As previously stated, each physical examination of the shoulder should begin with a cervical spine evaluation to determine whether it is contributing to the symptoms.^{8,11} Following this, the therapist begins with inspection of the shoulder girdle, dividing it into anterior, lateral, posterior, and superior aspects and looking for attitude, deformities, swelling and discoloration, and examining attitude and muscle characteristics.^{8,9,31,32}

During inspection, the attitude of the shoulder may present as being held in a "protected position" across the abdomen, often supported by the opposite extremity or

held higher than the opposite side as the patient attempts to guard against pain.³²

Deformities such as scars, tissue adhesions, and bony prominences may also prove to be meaningful. Tissue adhesions and bony prominences, such as enlargements of the SC and AC joints should be noted as they may be indicative of previous sprains. Squaring off of the shoulder with an anterior prominence of the humeral head may suggest glenohumeral subluxation or dislocation. Swelling is uncommon in most athletic shoulders, but discoloration from ecchymosis may be present from a recent rotator cuff injury.^{8,32}

Muscle symmetry and contours are also noted. The pitcher may demonstrate atrophy of the supraspinatus and/or infraspinatus fossa indicative of a large, chronic rotator cuff tear or suprascapular nerve dysfunction and may be shown by excessive prominence of the spine of the scapula. Wasting away of the infraspinatus muscle in its fossa below the spine of the scapula is a hallmark of a rotator cuff tear.^{8,32} A muscle often overlooked for its involvement in shoulder pathology is the biceps muscle. A “Popeye” appearance of the biceps during elbow flexion indicates a rupture of the long head of the biceps tendon which is often associated with rotator cuff pathology.^{11,32} Mild to moderate scapular winging is also commonly associated with cuff pathology as it may involve scapular stabilizer weakness and/or glenohumeral pathology and may be indicative of a long thoracic or spinal accessory nerve injury.^{3,8,11,32,33}

After inspection of the athlete’s shoulder, the therapist should then move on to palpation of specific areas of tenderness as this will further direct toward a specific injury finding. Once again, the shoulder should be regionalized so that anterior, lateral, posterior, and superior aspects can be palpated. Features to consider include tenderness,

swelling, temperature alterations, deformities, and attitude and muscle characteristic in relation to other structures.³² While tenderness of the biceps tendon over the bicipital groove may indicate biceps tendonitis, tenderness over the greater tuberosity alone may reveal a rotator cuff injury.^{8,32} The greater tuberosity is palpated by extending the arm, thus bringing the tuberosity from underneath the acromion. Pitchers with rotator cuff pathology may exhibit this tenderness over the greater tuberosity, where the supraspinatus tendon inserts.^{32,33} Posterior tenderness over the greater tuberosity may reveal infraspinatus tendon injury.⁸ Swelling and temperature changes should also be noted as possible evidence of an acute rotator cuff injury.

Following palpation of the athlete's shoulder, the therapist should move into testing of passive and active range of motion of both upper extremities for a comparison. Active range of motion (AROM) into all planes should be tested first, followed by passive range of motion (PROM) into those motions which presented with abnormalities. As was mentioned in chapter three, PROM examination in baseball pitchers often reveals increased external rotation and decreased internal rotation ROM, especially when tested in 90° elbow flexion and 90° of abduction.^{8,32,34} After range of motion, strength of the scapular muscles must be assessed. If there is a rotator cuff lesion, crepitus may accompany motion and the athlete may demonstrate weakness of abduction and/or internal rotation and external rotation.¹¹ In pitchers with decreased internal rotation and pain, anterior capsule laxity, posterior capsule inflammation, and contracture may add to their symptomatology.⁸ Deep tendon reflex testing of the triceps and biceps will be important for assessing brachial plexus involvement.^{11,23}

The next part of the evaluation of a pitchers throwing arm involves performing special tests in an attempt to again single out which part of the rotator cuff musculature is injured and what type of injury is present. There are numerous special tests used to examine different areas of the shoulder and rotator cuff including: the “shrug sign,” empty can test, lift-off test, drop-arm test, abrasion sign, Neer impingement sign, Hawkins-Kennedy test, and the impingement test.

The “shrug sign” is a test pertaining to the integrity of the supraspinatus muscle. The athlete attempts to “shrug” or elevate his affected shoulder. Limited or painful active elevation accompanied by scapular elevation and rotation as this glenohumeral elevation is attempted is a positive sign implicating supraspinatus involvement. The empty can test also checks the supraspinatus muscle. In this test, the patients shoulder is abducted to 90° with neutral rotation then internally rotated until the thumb points to the ground and angled forward 30° into the “empty can” or scaption position. Resistance to this abducted position is given by the therapist by pushing down on the pitcher’s arm. A positive test will present with weakness or pain and indicates supraspinatus involvement with a possible tear of the tendon or muscle.¹¹ The subscapularis is tested with the lift-off test. To conduct this test, the patient stands and places the dorsum of the hand on the back pocket and attempts to lift the now internally rotated hand away from the back. An inability to do so is a positive test and reveals a possible lesion, perhaps a subscapularis tear.^{8,11}

The drop-arm (Codman’s) and abrasion sign tests look at the rotator cuff complex as a whole. The drop-arm test passively places the athlete’s shoulder in 90° of abduction

with the elbow fully extended. The therapist then asks the patient to slowly lower the arm to the side in the same arc of movement that the therapist used to elevate it. A positive test is indicated if the patient is unable to return the arm slowly or experiences severe pain when attempting to do so, thus indicating a tear in the rotator cuff complex.¹¹ To perform the abrasion sign, which looks for crepitus in the shoulder, the pitcher's arm is placed in 90° of abduction with 90° of elbow flexion. The arm is then actively internally and externally rotated at the glenohumeral joint. If crepitus occurs, it is a sign that the rotator cuff tendons are becoming frayed secondary to abrading against the acromion process and coracoacromial ligament.¹¹

While weakness in elevation (shrug sign) is usually associated with complete tears of the supraspinatus, weakness in external rotation may indicate that the tear also involves the infraspinatus and possibly the teres minor muscles. Therefore, it is important to be thorough in the evaluation of special tests as well as strength testing and not to settle on one finding of a problem muscle with a discontinuation of the procedure. The rotator cuff muscles not only work together but are often injured together.⁸

Other special tests are aimed at trying to identify possible impingement signs in the pitcher. The Neer impingement test is conducted by forcibly elevating the patient's arm through forward flexion causing a "jamming" of the greater tuberosity against the anteroinferior border of the acromion. A positive test reveals pain and is indicative of an overuse injury to the supraspinatus and sometimes the long head of the biceps tendon secondary to impingement against the aforementioned structures.^{11,32} The Hawkins-Kennedy test is also directed at the supraspinatus muscle. This is performed by forward

flexing the patient's arm to 90° and then forcibly internally rotating it. This movement pushes the supraspinatus tendon against the anterior surface of the coracoacromial ligament. Pain reveals a positive test for supraspinatus tendonitis from overuse induced by impingement against the coracoacromial ligament. The impingement test places the pitcher's arm in 90° abduction and full external rotation in sitting. If there is no history of possible traumatic subluxation or dislocation, this movement can cause anterior translation of the humerus resulting in secondary impingement of the rotator cuff.^{11,32} Impingement signs tend to be less consistent in pitchers and other patients with internal impingement of the supraspinatus on the posterior superior glenoid, so other tests may prove to be more helpful.⁸

In the pitcher with rotator cuff pathology secondary to subtle anterior instability, mild to moderate increased anterior translation on the affected shoulder with laxity testing is usually demonstrated. The relocation (apprehension) test is useful in identifying athletes with subtle anterior laxity causing their symptoms. This test is performed with the patient in the supine position and the arm abducted and elbow flexed to 90° and shoulder externally rotated to full. A positive test is demonstrated by reduction of pain and apprehension when a posteriorly driven force is applied (thus restoring normal positioning) and is indicative of this subtle anterior instability and internal impingement.^{8,11} An athlete with posterior instability may also demonstrate voluntary subluxation of the humerus in a position of flexion, adduction, and internal rotation, but this is rare.⁸

In the pitcher who has rotator cuff pathology due to macrotrauma, physical findings will include tenderness over the superior aspect of the shoulder, limited AROM with possible palpable crepitus, and a positive shrug sign. Impingement signs are usually positive as well. If the cuff pathology results from an anterior glenohumeral dislocation, increased translation and a positive relocation (apprehension) test may be present. In these patients, deltoid function must be assessed carefully if a significant weakness of elevation is present. This will help rule out an axillary nerve injury.⁸

Routine radiographs, magnetic resonance imaging (MRI), X-rays, and other imaging studies are also important tools in the evaluation, if they are available. They can be useful in determining suspected muscles and tendons involved in a rotator cuff injury, acromion morphology, presence of a Bankart lesion on the glenoid rim, presence of calcific tendonitis, and superior migration of the humeral head.^{8,11}

Chapter 5

Treatment

Once a careful and thorough evaluation has been performed and diagnosis of the primary pathology and involved tissues have been identified, a rehabilitation program can begin to be assembled.²¹ When determining which rehabilitation program will be best for the athlete, the therapist must consider whether the treatment is utilizing a conservative or surgical management approach. Most rotator cuff injuries in baseball pitchers can be treated conservatively, but full thickness tears of the rotator cuff and those injuries that do not respond to conservative care within 3 to 6 months often require surgical repair to decrease pain and restore upper extremity function.^{21,35}

Regardless of the treatment option chosen, there are several principles that should be considered when formulating the rehabilitation program for the baseball pitcher. These principles include: minimizing the effects of immobilization; never overstressing healing or inflamed tissues; diminishing pain and inflammation prior to aggressive strengthening; treating the shoulder joint as one part of the kinetic chain; establishing proximal stability for distal mobility (i.e. scapular muscular strength); understanding that the key to the shoulder is the rotator cuff; acknowledging that there is more to the shoulder than just the rotator cuff; establishing dynamic joint stability before aggressively exercising for power and functional return; basing the rehabilitation program on current scientific and clinical research; and utilizing the team approach with the athlete, physical

therapist, physician, trainer, coach, etc., all working together toward a common goal of getting the pitcher back to competition at as close to normal function as possible.²²

Before the treatment of each class of mechanism of injury is discussed, some fundamental information about muscles must be discussed. To follow the progression of strengthening exercises in the rehabilitation protocol, it is important to understand the different types of muscle contractions and their involvement in exercise. There are three types of muscle contractions to consider: isometric, concentric, and eccentric. Isometric contractions are defined as muscle contractions in which no length changes take place in the muscle yet tension is developed. They are capable of developing more tension than concentric contractions, but because there is no length change in the muscle, no work is done by that muscle. Concentric contractions involve muscle shortening under a constant load or tension. This contraction develops positive work as it moves the load against which it is contracting. In an eccentric contraction the muscle lengthens under a constant load or tension due to the resistance overcoming the force being produced. Eccentric contractions are capable of developing more tension than either a concentric or isometric and produce negative work.³⁶

Knowledge of how each of these types of muscle contractions works is essential for a clear understanding of how and when to progress the athlete's rehabilitation program for treatment of one of the four primary categories of rotator cuff injury discussed in chapter three. The rest of this chapter will be spent detailing conservative

and postsurgical rehabilitation programs for each of these mechanisms of injury: primary impingement, primary tensile overload, instability, and macrotrauma. Because each of these mechanisms of injury may ultimately lead to a rotator cuff tear, rather than discussing rotator cuff tears for each category there will be a section reserved for a detailed discussion of rehabilitation of rotator cuff tears.

When discussing treatment of rotator cuff injuries in baseball pitchers, it is best to separate the rehabilitation into separate phases. However, exact time frames of each phase are beyond the scope of this review because the length of each phase depends on physician restrictions, severity of injury, patient tolerance and compliance with the rehabilitation program, and whether or not surgery was needed to repair the injury. Estimated time frames will be provided to help give a basic understanding of when to progress the athlete.^{37,38}

PRIMARY IMPINGEMENT

Over 90% of all impingement injuries respond to conservative management.^{19,21} For those pitchers that do not respond to a conservative program, a subacromial decompression and/or acromioplasty are the traditional surgical options. A subacromial decompression involves removing the anterior inferior surface of the acromion and coracoacromial ligament. An acromioplasty is typically performed in the presence of a type II (curved) or type III (hooked) acromion, and involves the shaving of that part of the acromion that is causing the impingement.^{8,22} These procedures can be done either with open exposure of the injured site or arthroscopically. The arthroscopic approach is

preferred for baseball pitchers as it allows evaluation of the glenohumeral joint and articular surface of the rotator cuff.⁸

Surgical examination of the area may reveal inflammation and synovitis superior to the biceps brachii insertion, especially in the presence of a rotator cuff tear. The subacromial bursa is usually inflamed and thickened secondary to being impinged repetitively during the pitching motion. If a less than 50% partial thickness rotator cuff tear is found with the arthroscopy, it must be debrided. The presence of a full thickness tear or partial thickness tear greater than 50% requires surgical repair of the rotator cuff. In each of these cases, the athlete will follow a rotator cuff tear rehabilitation protocol, which will be discussed later in the chapter.^{8,22}

The low success rate in returning athletes to competition after a surgical decompression reinforces the importance of conservative management in these pitchers.^(116,117,118) This low success rate is due to the fact that in the thrower, anterior glenohumeral instability is often present in addition to the anterior impingement. In the presence of instability, surgical procedures for impingement do not help because the humeral head can continue to migrate anteriorly and superiorly secondary to the anterior capsule laxity, thereby compressing the rotator cuff.¹⁹

Following a diagnosis of primary impingement with no evidence of a rotator cuff tear, the athlete must begin a rehabilitation program. Programs for conservative and post surgical rehabilitation have some differences between them. Typically surgical decompressions and acromioplasties tend to lag about two weeks behind conservative treatment for a couple of reasons. First, there is additional soft tissue healing from the

surgery. Second, different surgeons have different protocols to follow with different time frames and criteria for phase advancement within their protocol, so athletes may be progressed at different rates in different clinics.

Phase I

Phase I, or motion phase, emphasizes re-establishing nonpainful range of motion (ROM), retarding muscle atrophy, and decreasing pain and inflammation. It begins with passive range of motion (PROM) and active assistive range of motion (AAROM) exercises on the first day of rehabilitation following surgery. This may be accomplished using Codman's pendulum exercises, a rope and pulley mechanism, and wand exercises into flexion and extension, abduction and adduction, and external rotation and internal rotation of the shoulder joint. Self-stretches to stretch the capsule may also be initiated. The athlete should begin these exercises in 10° to 20° shoulder abduction or with a pillow under the arm to allow some abduction (to prevent wringing out of the supraspinatus circulation at the critical zone), progress to 45° abduction, and finally perform them in 90° abduction. This will allow time for tissues to heal and prevent the athlete from performing the exercises in a painful position.^{21,22}

Isometric shoulder strengthening exercises for the shoulder and scapulothoracic musculature are initiated at this time to facilitate stabilization of the shoulder complex. These exercises involve manual resistance from the therapist and should be performed at multiple angles. Research shows that strength gains are in a range 20° on either side of the angle at which the exercise has occurred.^{37,38} Thus, performing the isometrics at multiple angles ensures strength gains throughout the full ROM. External rotation and

internal rotation are very important and should be performed with the arm in about 20° shoulder abduction with 90° elbow flexion. Later in the phase, exercise tubing resistance exercises may be started in 20° shoulder abduction to increase internal and external rotation strength. Treatment sessions in this phase are ended with pain and inflammation control using ice, nonsteroidal anti-inflammatory medications (NSAIDS) prescribed by the physician, and modalities as indicated. Throughout this phase, positions of impingement are to be avoided. Once the athlete is able and active and resistive exercises are begun, the athlete can advance to Phase II.^{8,22}

Phase II

The goals in Phase II are to regain and improve muscular function, normalize arthrokinematics, and improve neuromuscular control of the shoulder complex with full ROM, minimal pain and inflammation, and “Good” (4/5) grade manual muscle tests for all shoulder motions. These goals are attained through a concentric strength program for shoulder and scapular musculature. Concentric exercises may begin with exercise tubing for resistance and progress to light weight dumbbells to help increase strength. Figure 10 gives examples of exercise tubing exercises for strengthening of the deltoid and rotator cuff musculature. Joint mobilizations and AROM exercises aid in restoring arthrokinematics. Trunk and upper extremity endurance exercises are initiated to improve overall shoulder stabilization and function. The upper extremity bicycle ergometer can be utilized early in this phase as it promotes ROM, shoulder endurance, and increases blood supply to the healing tissues.^{37,38} Continued use of modalities and ice as needed are prescribed for control of pain and inflammation.^{8,22}

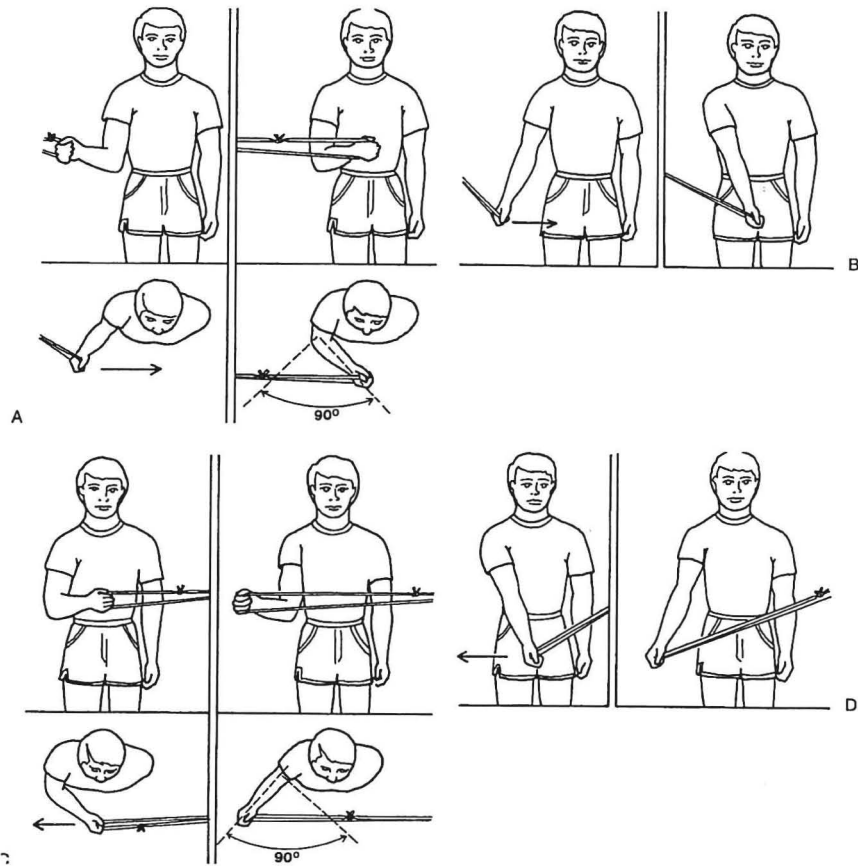


Figure 10. Use of elastic tubing to strengthen rotator cuff and deltoid muscles. (A) Internal rotation, (B) Horizontal adduction, (C) External rotation, (D) Abduction. (From Andrews²² et al with permission).

Phase III

Criteria to enter Phase III of the rehabilitation program include: full pain free ROM, no pain or tenderness, and strength of the involved shoulder at 70% compared to the uninvolved side. Goals of this phase are geared toward improving strength, power, endurance, neuromuscular control, and preparing the athlete to throw. This phase works on high speed, high energy strengthening exercises, eccentric exercises, and diagonal patterns. Exercises in Phase III may include: continued dumbbell strengthening of the

supraspinatus and deltoid, exercise tubing exercises for internal and external rotation in a 90° shoulder abduction and 90° elbow flexion position including slow and fast sets, elastic tubing and light weight dumbbell exercises for the scapular muscles and biceps brachii, low level plyometrics for rotator cuff strengthening, continued endurance exercise, and initiated isokinetic training. Table 3 gives examples of plyometric exercise to use with baseball pitcher rehabilitation and normal conditioning as well.^{8,22}

TABLE 3. PLYOMETRIC EXERCISES FOR BASEBALL PITCHERS

<u>Warm-up Exercises</u>	<u>Torso Exercises</u>
Torso Circles Good Mornings Woodchoppers Medicine Ball Side Bends	Medicine Ball Sit-up Medicine Ball Sit-up and Twist Rocky Half Twist Side to Side Passes
<u>Throwing Exercises</u>	<u>Whole Body Exercises</u>
Soccer Throw Overhead Single Arm Throw Single Arm Bounce Throw Pullover Throw	Medicine Ball Squat and Throw Overhead Backward Throw Forward Through the Legs Tip Drill

Phase IV

Phase IV can begin once the pitcher has full AROM, no pain, and an isokinetic test that demonstrates 90% strength and 90% endurance of the rehabilitated upper extremity compared to the contralateral upper extremity. This phase emphasizes progressively increasing the pitchers activities to prepare the athlete for full functional return to competition. When these criteria are met, the pitcher can begin an interval throwing program that progressively increases distance and repetition as is indicated.

The athlete should continue with all the strengthening and stretching exercises used in Phase III. A comprehensive exercise program should be developed for lower extremity, trunk, and upper extremity strength and endurance training. The throwing and upper extremity training should be done on the same day, while a lower extremity workout and shoulder ROM exercises should be performed on opposite days of throwing.^{8,22}

TABLE 4. EXERCISES FOR STRENGTHENING SCAPULAR MUSCLES

1. Serratus Anterior	Serratus Punches, Push-ups with a Plus, Quadruped Stabilizations, Shrugs, Abduction in the Scapular Plane, Prone Shoulder Flexion
2. Rhomboids Major and Minor	Shrugs, Rowing, Scapular Retractions
3. Pectoralis Major and Minor	Press-ups, Bench Press
4. Levator Scapulae	Rowing, Shrugs, Shoulder Abduction
5. Latissimus Dorsi	Press-ups, Lat Pull Downs
6. Upper Trapezius	Shrugs, Abduction in the Scapular Plane, Rowing
7. Middle Trapezius	Rowing, Scapular Retraction with the Arm in 90° Abduction, Prone Shoulder Flexion and Abduction
8. Lower Trapezius	Rowing, Scapular Depression and Retraction, Abduction in the Scapular Plane

PRIMARY TENSILE OVERLOAD

A diagnosis of primary tensile overload (failure) will result from repeated eccentric tensile overload during the deceleration phase of throwing. This tensile overload usually produces partial undersurface tearing of the rotator cuff secondary to

repetitive microtrauma. The majority of pitchers with primary tensile overload respond well to a conservative rehabilitation program.⁸ For those athletes who do not respond to a conservative program, surgical intervention may be indicated for examination of the structures in question of possible injury. In any case, treatment begins with a decrease in throwing by the pitcher. This is essential in preventing further damage to the already compromised tissues.^{8,22}

A gradual and progressive strengthening program for the involved tissues can be initiated in early rehabilitation. This is accomplished through exercise tubing exercises and by progressing to free weights as indicated into all shoulder motions. Advanced strengthening utilizes plyometrics as a major component to enhance strength of the posterior shoulder musculature. Plyometric external rotation and posterior deltoid strength drills are utilized with a two-handed overhead side throw, a one-hand baseball throw, and step and throw exercises with medicine balls of varying weights. Exercises to promote posterior deltoid strength are employed in hopes of diminishing stress on the posterior rotator cuff muscles. Additionally, the therapist can use plyometric drills with a medicine ball rebound machine to create functional movement patterns and to simulate throwing.^{8,22}

Examination under anaesthesia and arthroscopy should be performed if there is no improvement within three months of conservative rehabilitation. The subacromial space is usually found to be normal in these athletes and a subacromial decompression or acromioplasty is usually not needed.⁸ In fact, these surgical options may lead to further glenohumeral instability.^{8,21} This occurs because when the rotator cuff fatigues as a result

of repetitive overload, not only is decelerative function affected, but the stabilization function of the involved muscles is also impaired. Thus, by shaving part of the acromion process or removing part of the coracoacromial ligament and taking away some of the supporting structures, glenohumeral instability is further increased.³⁹ Partial thickness rotator cuff tears of less than 50% should be debrided, and partial thickness tears greater than 50% and full thickness rotator cuff tears must be surgically repaired. Pitchers undergoing procedures for these complications will follow a postsurgical rehabilitation protocol for rotator cuff tears.^{8,22}

These are some basic essentials for conservative and postsurgical rehabilitation of primary tensile overload, but because this diagnosis is usually accompanied by partial undersurface rotator cuff tears, these athletes often follow a rotator cuff tear rehabilitation program. A detailed look at this rehabilitation program will be presented later in the chapter, so a more comprehensive look at a protocol for this diagnosis, can be found in that section.

GLENOHUMERAL INSTABILITY

A diagnosis of glenohumeral instability with recurrent anterior subluxation of the shoulder is the single most important problem in the throwing athlete.¹⁹ Severe stresses placed on the anterior capsular structures during the arm cocking phase of pitching can result not only in injury to the capsule, leading to instability, but injury to the labrum as well. This results from the anterior inferior glenohumeral ligament, which inserts into the labrum, being overstretched in the arm cocking phase of pitching while the arm is in maximal external rotation and abduction, thus leading to impingement. Most pitchers do

not have true glenohumeral instability, but rather exhibit an acquired excessive laxity from repetitive throwing and stressing with resultant stretch of the anterior capsule. Early identification is difficult, but essential for successful treatment. If this instability is left untreated, it can lead to secondary problems resulting in rotator cuff tears.^{19,21,22} Treatment for instability can include a conservative or postsurgical rehabilitation program. A conservative program is only successful if the athlete stops pitching and throwing completely following diagnosis.^{8,22}

Conservative Treatment for GH Instability

The conservative rehabilitation for anterior shoulder instability will vary in length depending on the degree of shoulder instability or laxity, whether the condition is acute or chronic, the current condition of strength and ROM status, and the activity performance demands of the individual pitcher. The treatment program is detailed in three phases. In the first two phases all exercises must be performed with no undue stress on the anterior joint capsule.²²

Phase I

In phase I, pain and inflammation can be controlled through the use of modalities such as heat, ice, and electrical stimulation. Range of motion exercises are performed as tolerated. For shoulder abduction and external rotation, avoid stress to the anterior joint capsule by positioning the shoulder in the scapular plane. Hyperextension of the shoulder is contraindicated.²² External rotation exercises are done with the arm in 10° to 20° abduction in the scapular plane with 90° elbow flexion and limited to 45° of motion. Posterior rotator cuff and capsule stretches and posterior glide joint mobilizations are the

only stretches to be performed and only if they are necessary to increase ROM and joint play.^{19,22}

Active shoulder internal rotation, external rotation, flexion, and abduction strengthening exercises with exercise tubing are performed with the arm positioned at the side in the scapular plane and the elbow flexed to 90°. Abduction and external rotation are limited to 45° to avoid undue stress to the anterior capsule. Supraspinatus exercises are performed in the scapular plane. Shoulder extension exercises, lying prone or standing and bending at the waist, are performed while avoiding hyperextension by not allowing the arm to extend beyond the plane of the body. Active horizontal abduction is done in the supine position, starting with the arm in the scapular plane. All of these exercises are progressed to free weight exercises for advanced strengthening as indicated. Stress on the anterior capsule can be avoided by limiting all of the movements to 45° to 50° of motion. At this time, elbow, wrist, and forearm ROM and strengthening exercises can be initiated for the involved upper extremity as these joints can be affected with stiffness and edema due to decreased use of the shoulder.^{19,21,22}

Phase II

Phase II emphasizes eccentric and isokinetic strengthening exercises for internal and external of the shoulder. These exercises are performed with the arm in 10° to 20° abduction in 15° to 20° of shoulder flexion while avoiding painful external rotation and at higher speeds (e.g. 200 °/s or more). Push ups should be added to the strengthening regimen. Movement should be pain free and the athlete should progress the push up exercise moving through the levels of difficulty as able. For example, begin with push

ups against the wall in standing, progress to modified push ups on the knees, and finally end with military push ups (on toes). Stress to the anterior capsule can be avoided by maintaining proper alignment of the shoulders and elbows at the starting position, and by not lowering the body beyond the elbows. Shoulder strengthening with exercise tubing and/or free weights should be continued while now emphasizing the eccentric contraction of the muscles. Range of motion exercises, posterior rotator cuff and capsule stretches, and posterior joint mobilizations should be continued as needed. An ergometer program can be initiated to increase the patient's endurance and ROM of the shoulder using the upper extremity bicycle ergometer. A total body conditioning program should also be added with emphasis on strength and endurance while incorporating flexibility exercises as needed.^{19,21,22}

Phase III

In phase III, stress is gradually applied to the anterior capsule by allowing isokinetic internal rotation and external rotation exercises to be performed with advancing degrees of shoulder abduction. Shoulder abduction with this isokinetic program should progress from 10° to 45°, and then from 80° to 90° abduction as tolerated. By progressing the abduction position, the athlete will be exercising in an increasingly sport specific position of pitching. Once 90° of shoulder abduction is reached, the athlete should be ready to begin isokinetic exercises for shoulder flexion, extension, abduction, adduction, horizontal abduction, and horizontal adduction. Caution is advised to avoid excessive stress to the anterior joint capsule. Chin ups may be added for latissimus dorsi

and biceps brachii strengthening. Posterior rotator cuff stretching is continued as needed and the upper extremity bicycle ergometer is continued for endurance training.²²

Once the shoulder is pain free with no swelling and an isokinetic test for shoulder internal and external rotation demonstrates at least 90% strength and 90% endurance compared with the uninvolved upper extremity, a progressive interval throwing program can begin. Advancement through this throwing sequence occurs as needed, and the therapist needs to make the determination along with the rehabilitation team on when a practice of sport specific activities can begin so the athlete can take to the mound and begin drills specific to pitching.^{19,21,22}

If the conservative rehabilitation program fails after 3 months, surgery is generally indicated. The surgical treatment of moderate and severe anterior glenohumeral instability has centered around repair of a Bankhart lesion when present and various anterior capsular reconstruction procedures such as the capsulolabral reconstruction, Bristow, Magnusson-Stack, and Putti-Platt techniques.^{8,19,21,22} The latter two are not recommended for athletes who will be throwing, as they tighten the shoulder so much that the athlete is left with limited mobility.⁸ A detailed look at these procedures individually is beyond the scope of this literature review. However, a general postsurgical rehabilitation program will be appropriate and beneficial to the understanding of how to progress a pitcher who has undergone an operation for glenohumeral instability.

Postsurgical Rehabilitation Program

In general, rehabilitation for the pitcher with a secondary diagnosis of post-surgical glenohumeral instability can be divided into four phases.^{8,19,21,22} Phase I begins with the athlete immobilized in an abduction brace for approximately four weeks. In the past, the immobilization brace was kept on all the time, but new advances in the treatment of postsurgical rehabilitation now allow the pitcher to use a sling during the day for the first two weeks and put the brace on only when sleeping.²² This shoulder immobilization brace is placed in a position of 90° abduction, 30° forward flexion, and 45° external rotation. This position allows the athlete to regain full ROM and is optimal for the throwing athlete as it places the shoulder in external rotation and prevents tightening of the anterior and inferior capsule.²¹

Phase I

The first phase of rehabilitation lasts about six weeks and has the athlete in this immobilization brace for four weeks while sleeping and in a sling for comfort for the first two weeks after surgery. Gentle active assistive ROM exercises (AAROM) with wand into forward flexion from 0° to 60°, external rotation (at 20° abduction) with maximal motion to 0°, and internal rotation (at 20° abduction) with maximal motion to 45° are begun immediately to try to regain ROM as soon as possible. The athlete should not abduct past 20° or externally rotate the shoulder during the first four weeks. Elbow and hand ROM exercises and isometric exercises should be performed at a submaximal and subpainful level in 20° shoulder abduction to aid with reduction of edema and stiffness that may occur due to the decreased use of the involved shoulder and the rest of the upper extremity. Ice and modalities are applied to the shoulder as needed to control pain and

inflammation. Weeks 3 to 4 begin with discontinued use of the sling during the waking hours, but continued use of the abduction brace for sleeping. Active assistive range of motion exercises with the wand are continued. Forward flexion should reach 0° to 90°, external rotation (in 20° shoulder abduction) reaching a maximal motion of 25°, and internal rotation (in 20° shoulder abduction) reaching a maximal motion to 65°. The athlete should continue performing isometric and ROM exercises of the elbow and hand as well. Weeks 5 through 6 begin with discontinued use of the immobilization abduction brace altogether. Active assistive range of motion exercises with the wand should gradually progress into all motions with flexion reaching 0° to 135°, external rotation (at 45° shoulder abduction) to 30°, and internal rotation (at 45° shoulder abduction) to 60°. Light weight isometric exercises for external and internal rotation, abduction, supraspinatus, and elbow flexion and extension should be initiated to increase strength. Also, light free weight scapular strengthening exercises for protraction, retraction, elevation, and depression will be helpful in strengthening the entire shoulder. The UBE should be used to increase endurance, beginning with the shoulder in 70° shoulder abduction.^{8,21,22}

Phase II

Phase II, or moderate protection phase, runs through week 14. Weeks 7 through 9 begin with progressing all motion exercises toward full ROM. Goals for forward flexion are from 0° to 180°, external rotation (at 90° shoulder abduction) to maximal motion of 75°, and IR (at 90° shoulder abduction) to maximal motion of 85°. The athlete should continue the concentric free weight shoulder and scapular strengthening program. A

diagonal strengthening program is initiated in this phase. This is accomplished by moving into a D2 proprioceptive neuromuscular facilitation (PNF) extension pattern. Proprioceptive neuromuscular facilitation is a set of precise movement patterns that are developmentally set in humans. The patterns involve a diagonal component of flexion, extension, abduction or adduction, and rotation about the shoulder, elbow, and wrist. The athlete can progress the diagonal strengthening from lying supine to standing to standing while using exercise tubing.²²

An isokinetic strengthening program for external and internal rotation should be initiated starting at 20° abduction and using high speeds. Concentric strengthening exercises using exercise tubing should be done for external and internal rotation also beginning in 20° of abduction. This strengthening involves progressing the resistance in concentric exercises and focusing on strength and control through eccentric muscle contractions. The exercise will focus on the rotator cuff and scapular stabilizers in the beginning of this phase and other prime movers of the shoulder later in this phase. This allows the rotator cuff and scapular muscles to be strong for stabilization of the shoulder before the prime movers become strong, challenging the balance of the shoulder complex. By weeks 8 to 9, full AROM should be achieved. Weeks 10 to 14 continue with and progress all exercises as stated above. A manual resistance exercise program for shoulder strengthening may also be initiated.^{19,21,22}

Phase III

Phase III, the minimal protection phase, begins at week 15 and ends around week 21. Weeks 15 to 18 are spent continuing with all flexibility exercises and capsular

stretches to maintain full ROM. The Throwers Ten program should be initiated (see table 5) along with light swimming and exercises in the 90° of shoulder abduction position. Weeks 18 to 21 continue with flexibility exercises. An interval throwing program should be initiated when: full, nonpainful ROM is achieved; strength of the involved shoulder is 90% of the contralateral side via the isokinetic test; no pain or tenderness is noted; and the pitcher receives a satisfactory clinical examination from the surgeon (see Table 7). A plyometric exercise program should be started and the athlete should continue with his Throwers Ten program.^{2,22}

Phase IV

Phase IV, the advanced strengthening phase, consists of an aggressive strengthening program for the shoulder and scapular musculature. Continued Throwers Ten exercises and plyometrics are essential, and the pitcher should progress the interval throwing as is indicated. This phase runs through week 26 postsurgery.

The pitcher may not be able to return to unrestricted throwing for up to 9 months. During this time and after the injury is fully recovered, the athlete is encouraged to continue with all the advanced strengthening, endurance, and stretching exercises along with a consistent throwing program. This will provide for proper care of an already vulnerable throwing arm and help prevent future injuries from occurring.^{21,22}

MACROTRAUMA

A pitcher with a diagnosis of macrotrauma as the mechanism of injury is first treated with a conservative program of rehabilitation. The type of program initiated depends on what secondary complications are found. For example, if impingement is

found, the athlete will begin a program for impingement syndrome similar to the one detailed earlier in the chapter. If the conservative program fails, surgery is indicated. An arthroscopy may be performed to examine the injured area for presence of a Type II or Type III acromion or for the presence of partial and full thickness rotator cuff tears that may have been sustained during the trauma or secondary to impingement. If the acromion morphology shows that it is causing the secondary complaints, an acromioplasty may be done. If tears in the rotator cuff are found, they will be debrided (if less than 50% tear) or repaired surgically (if greater than 50% tear). Following the surgery, the athlete will follow the postsurgical rehabilitation program specific to the injury suffered.^{8,22}

ROTATOR CUFF TEAR

Rotator cuff tears can be the result of chronically untreated impingement, tensile overload, instability, and macrotrauma. A quick overview of chapter three shows that: impingement can lead to overuse tendonitis with repetitive microtearing and microtrauma occurring to the involved rotator cuff muscle(s), usually the supraspinatus; tensile overload may begin as a microtear and, through repetitive throwing, lead to microtrauma, partial thickness tears, and finally to full thickness tears of the involved rotator cuff muscle(s), usually the infraspinatus and teres minor; instability can lead to a rotator cuff tear through secondary problems associated with impingement; and macrotrauma, also through secondary complications or the direct trauma, can result in tears of the rotator cuff that must be treated accordingly.^{8,10,22}

The last section of this chapter will be spent detailing a general rotator cuff tear rehabilitation protocol. Like an impingement injury to the rotator cuff, conservative and

postsurgical rehabilitation programs can be discussed together in a four-phased treatment approach. However, some differences do exist between the two. Tears requiring surgical repair tend to lag 4 to 6 weeks behind tears managed conservatively. This occurs for a few reasons. First, there is extra soft tissue healing from the surgical procedure that must take place. Secondly, surgeons immobilize the shoulder to allow for adequate tendon-bone healing after the surgery. The length of this immobilization varies from surgeon to surgeon, but literature states it may extend anywhere from 4 to 6 weeks postoperatively. Lastly, restrictions on active abduction and flexion lasting up to 6 weeks postoperatively slow the rehabilitation process.^{37,38}

This literature review will detail a relatively advanced rehabilitation protocol with the latest advances in progression of exercises as is found in the literature. It is designed to get the pitcher back to a throwing program earlier (at 18-24 weeks post operatively) so that the athlete may return to sport specific activities of pitching a baseball as soon as possible without jeopardizing the rotator cuff to further injury by throwing too soon after surgery. Specific time frames are beyond the scope of this review as different physicians will have different time frame recommendations, but a general time line is provided.

Phase I

Phase I, the protective phase, emphasizes controlling pain and inflammation, achieving near full ROM, and initiating flexibility and stretching exercises. Goals of this phase are to: protect the repaired rotator cuff and promote healing; gradually restore shoulder motion; and diminish pain and inflammation. Week one begins with bracing the shoulder for everyday activities and sleeping. Passive range of motion and AAROM

exercises using a wand, rope and pulley, and Codman's pendulum exercises (beginning with small circles) are all initiated to regain ROM into flexion, extension, and external and internal rotation. Elbow ROM and hand gripping exercises are begun to minimize muscle atrophy and ROM loss. Isometric strengthening exercises at a submaximal and subpainful level are initiated for the abductors, external rotators, internal rotators, and flexors of the shoulder. Pain and inflammation are controlled through modalities (ice, HVGS, etc.), and anti-inflammatory medications prescribed by the physician.^{2,22}

Week 2 continues with use of the brace for everyday activities and for all exercises outlined above. Active assistive flexion with the wand is initiated to further increase ROM. Pendulum exercises can progress from small circles to incorporating a forward and backward movement into flexion and extension. The therapist can begin to gradually progress arm adduction motion, gradually allowing the arm to return to the side.^{2,22}

Week 3 begins with initiating ROM exercises with the wand into flexion and extension in supine, external and internal rotation (10° shoulder abduction), and external and internal rotation in the scapular plane. Strengthening exercises using exercise tubing for external and internal rotation (10° shoulder abduction) are also begun. Rhythmic stabilization exercises with the arm at 100° to 125° flexion are performed for resisted flexion, extension, and horizontal adduction and abduction. Exercises for external and internal rotation rhythmic stabilization in the scapular plane should also be started. Isometrics are continued for shoulder flexion and extension, elbow flexion, and shoulder abduction. Range of motion stretching exercises and use of abduction brace in 25° is continued.^{2,19,22}

Week 4 should continue with all ROM exercises listed above as well as the use of the abduction brace or even a pillow to maintain the shoulder in 25° of abduction during sleeping and everyday activities. A gentle external and internal rotation stretching program at 90° shoulder abduction should be initiated by this time. Finally, all strengthening exercises listed above should be continued. Humeral head stabilization exercises performed at 30°, 75°, 100°, and 125° of shoulder flexion, external and internal rotation concentric exercises with exercise tubing, and all the isometrics previously mentioned are done to enhance strengthening of the shoulder musculature.

Week 5 and 6 are included together in the rehabilitation program. Week 5 begins with discontinued use of the abduction brace. Range of motion exercises of: AAROM with the wand, Codman's pendulum exercises, flexion and extension with the wand, rope and pulley, and gentle external and internal rotation capsular stretches should all be continued. All strengthening exercises listed above should be continued and progressed as needed. Shoulder abduction and flexion should be progressed to strengthening with the weight of the arm as the resistance. Biceps brachii and triceps brachii strengthening should also be initiated.^{2,8,22}

Phase II

Phase II, the intermediate phase, strives to reach full, nonpainful ROM; restoration of strength and endurance; and increased functional activities. Week 7 continues with AAROM wand and rope and pulley ROM exercises. Self-scapular stretches and joint mobilization techniques are initiated in this phase. Strengthening exercises as listed above are continued, and scapular musculature neuromuscular control drills are initiated. Also,

prone horizontal abduction to neutral, prone horizontal abduction with full external rotation at 100°, and prone rowing exercises are also initiated for strengthening of the rotator cuff musculature.

Weeks 8 to 12 continue with the above ROM exercises and initiate gentle contract-relax PNF motions to increase motion for those that are still restricted. Strengthening exercises now progress to initiate the Throwers Ten program of light resistance movements (see table 5). All exercises mentioned above are continued, along with manual resistance exercises into D2 extension and flexion patterns with rhythmic stabilization, and external and internal rotation rhythmic stabilization in the 90° shoulder abduction and 90° elbow flexion position are initiated to further enhance strength of the rotator cuff musculature. The rest of this phase is spent continuing with all the exercises listed above.^{2,22}

TABLE 5. THROWER'S TEN PROGRAM

- | |
|--|
| <ol style="list-style-type: none">1. Diagonal D2 Patterns for Shoulder Extension and Flexion with Exercise Tubing2. Dumbbell Exercises for Deltoid and Supraspinatus Strengthening3. Prone Shoulder Abduction Diagonal D2 Flexion for Rhomboids with Exercise Tubing4. Prone Shoulder Extension for Latissimus Dorsi Strengthening5. Internal and External Rotation at 90° Abduction with Exercise Tubing6. Biceps Strengthening with Exercise Tubing7. Dumbbell Exercises for Triceps and Wrist Extensors/Flexors8. Serratus Anterior Strengthening Exercises with Push-ups with a Plus9. Press-ups (seated)10. Rowing Lying Prone with a Dumbbell |
|--|

Phase III

Phase III is the advanced strengthening phase with goals to: improve strength, endurance, and power; gradually increase stress on healing tissue; and prepare to return to

throwing activities. Weeks 12 to 14 continue with ROM and stretching exercises including AAROM with the L-bar, capsular stretches, and contract-relax stretches. Strengthening exercises continue with the Throwers Ten program, continued D2 flexion and extension manual resistance exercises, and scapular neuromuscular control exercises. New exercises added to the program include: seated rowing, latissimus dorsi pull down, scapular depression with manual resistance, medicine ball side to side twists, medicine ball diagonals, medicine ball squats, and closed kinetic chain exercises of arm circles against the wall (flexion and scapular plane), and arm horizontal abduction and adduction against the wall.

Weeks 14 to 16 continue with all exercises listed in weeks 12 to 14, and initiate new medicine ball plyometric throwing drills of: two hand side-to-side throws, two-hand overhand side throws, two-hand underhand side throws, two-hand chest passes, and two-hand soccer throws. These activities should progress to one-handed baseball throws and wall dribbling with a basketball. The latter part of this phase initiates a phase I interval throwing program. (see table 7). All exercises listed above are continued.^{2,22}

Phase IV

Phase IV of the rehabilitation is the return to activity phase. At this time, the pitcher should have full ROM, pain and tenderness should be absent, isokinetic testing should reveal strength at 90% compared to the contralateral side, and the interval throwing program should progress to phase II. The athlete should continue with all strengthening and flexibility exercises as mound throwing begins. The athlete is encouraged to continue with proper warm-up, strengthening, and endurance training throughout the entire career.

There are six exercises for the rotator cuff that have been identified as essential to improve and maintain strength of the rotator cuff muscles (see Table 6).^{2,22}

This interval throwing program will continue with the same cycle through 14 stages. It progresses from the 90 feet to 120 feet, 150 feet, 180 feet, and ends with unrestricted throwing activities for the athlete. The pitcher should be progressed through the program as tolerated and indicated. When the athlete reaches the unrestricted stage of the throwing program, he can begin increasing throwing velocity to competitive levels.^{19,22}

TABLE 6. "ESSENTIAL SIX" ROTATOR CUFF STRENGTHENING EXERCISES

<u>Exercise</u>	<u>Muscle Involved</u>
Empty Can	Supraspinatus
Horizontal Abduction at 90°	Infraspinatus
Horizontal Abduction at 100°	Supraspinatus
Side-Lying External Rotation	Teres Minor and Infraspinatus
Prone External Rotation	Infraspinatus and Teres Minor
Prone Extension	Teres Minor

TABLE 7. SAMPLE INTERVAL THROWING PROGRAM

<p>Step 1: 45 Feet</p> <p>A. Warm-up throwing</p> <p>B. 45' (25 throws)</p> <p>C. Rest 15 minutes</p> <p>D. Warm-up throwing</p> <p>E. 45' (25 throws)</p> <p>Step 2: 45 Feet</p> <p>A. Warm-up throwing</p> <p>B. 45' (25 throws)</p> <p>C. Rest 10 minutes</p> <p>D. Warm-up throwing</p> <p>E. 45' (25 throws)</p> <p>F. Rest 10 minutes</p> <p>G. Warm-up throwing</p> <p>H. 45' (25 throws)</p>	<p>Step 3: 60 Feet</p> <p>A. Warm-up throwing</p> <p>B. 60' (25 throws)</p> <p>C. Rest 15 minutes</p> <p>D. Warm-up throwing</p> <p>E. 60' (25 throws)</p> <p>Step 4: 60 Feet</p> <p>A. Warm-up throwing</p> <p>B. 60' (25 throws)</p> <p>C. Rest 10 minutes</p> <p>D. Warm-up throwing</p> <p>E. 60' (25 throws)</p> <p>F. Rest 10 minutes</p> <p>G. Warm-up throwing</p> <p>H. 60' (25 throws)</p>	<p>Step 5: 90 Feet</p> <p>A. Warm-up throwing</p> <p>B. 90' (25 throws)</p> <p>C. Rest 15 minutes</p> <p>D. Warm-up throwing</p> <p>E. 90' (25 throws)</p> <p>Step 6: 90 Feet</p> <p>A. Warm-up throwing</p> <p>B. 90' (25 throws)</p> <p>C. Rest 10 minutes</p> <p>D. Warm-up throwing</p> <p>E. 90' (25 throws)</p> <p>F. Rest 10 minutes</p> <p>G. Warm-up throwing</p> <p>H. 90' (25 throws)</p>
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APPENDIX



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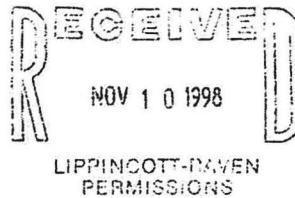
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3. Figure 7-8 page 96 - Theraband exercises to strengthen rotator cuff and deltoid
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